NASA-CR-199612

FINAL
IN-24-CR
OCIT
5427

P-3

Modeling of Outgassing and Matrix Decomposition in Carbon-Phenolic Composites
NASA Marshall Grant NAG8-295

Final Report

Covering progress in the period
July 1994 through October 1995

Submitted to Dr. Roy Sullivan
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October 1995

by

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(NASA-CR-199612) MODELING OF OUTGASSING AND MATRIX DECOMPOSITION IN CARBON-PHENOLIC COMPOSITES Final Report, Jul. 1994 - Oct. 1995 (MIT) 3 p

N96-70340

Unclas

Z9/24 0076342

Introduction

This is the final report on the "Modeling of Outgassing and Matrix Decomposition in Carbon-Phenolic Composites" program. Progress from July 94 through the termination of the contract in August 95 is summarized, and a final report in the form of an attached Master's thesis is submitted.

Progress

Work in this period concentrated on the development of a massively parallel computational algorithm for ablative composite computations. The ablative composite code CHAR was re-coded using the explicit finite difference method on the CM5 Massively Parallel Machine that MIT has acquired recently. The resulting code was verified by comparison to existing exact solutions for transpiration cooling problems and existing codes for simple ablative composite scenarios. Work continued past the original termination date under a no-cost extension.

A fundamental limit was found to the efficiency of massively parallel computations of this type. The critical time step required for stability was found to differ by many orders of magnitude both between different parts of the calculation (e.g. stress calculations required a much smaller time step than thermal ones) and between different regions (e.g. the fluid flow calculations required very different time steps in the charred region of the ablator than in the uncharred region). This problem was severe enough to make fully explicit calculation of the ablative problem computationally intractable.

A hybrid explicit-implicit code was therefore developed. It very efficiently solves the thermal, chemical, and mass flow problems using a massively parallel explicit algorithm. It breaks out the aspects of the problem which cannot be solved in reasonable times using an explicit algorithm: the stress problem (which is solved as a quasi-static secondary problem only when output is required or failure calculations are performed) and the mass flow problem in the charred area (which is solved by a quick implicit finite difference calculation at every time step). This code was exercised on several ablative problems, and was found capable of handling both ply-lift and RTG type calculations. Its performance was also measured using standard metrics of performance for parallel algorithms, and it was found to be 97% parallel in practical cases. This resulted in a 32 processor parallel solution running 20 times faster than the solution on a single workstation.

Two technical papers have been written and presented at conferences based on this work [1-2], graduate student David Shia has completed his Master's Thesis [3], and an archival paper based on reference [2] is in preparation. Copies of references [1-3] are attached.

Current Status

The project has been terminated. This is the final report.

References

[1] McManus, H. L., and Shia, D., "A Massively Parallel Computational Approach to Coupled Thermoelastic/Porous Gas Flow Problems", Proceedings of the 1994 JANNAF Rocket Nozzle Technology Subcommittee Meeting, Chemical Propulsion Information Agency, Columbia, Maryland, November 1994.

[2] Shia, D., and McManus, H. L., "Modeling of Composite Ablators Using Massively Parallel Computation", 36th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference, New Orleans, LA, April 1995, pp. 1371-1379.

[3] Shia, David, "Analysis of Composite Ablators Using Massively Parallel Computation", Master's Thesis, MIT, August 1995.

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